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DECLARATION



I, Kazuo EDA, residing at 7th FL., SHUWA KIOICHO PARK BLDG., 3-6, KIOICHO, CHIYODA-KU, TOKYO, JAPAN, hereby declare that I have a thorough knowledge of Japanese and English languages, and that the attached pages contains a correct translation into English of the application document of Japanese Patent Application No. 11-097852 filed on April 5, 1999, in the name of CANON KABUSHIKI KAISHA.

I further declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statement were made with the knowledge that willful false statements and the like so made, are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Signed this 6th day of January, 2003

Kazuo EDA

Kazuo EDA

Translation of Japanese Patent Application No. 11-097852

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ELECTRON SOURCE APPARATUS AND IMAGE FORMING APPARATUS

[What Is Claimed Is:]

5 [Claim 1]

 An electron source apparatus which has an electron source and a counter substrate arranged to face the electron source and in which the electron source has on a substrate a plurality of row-direction wiring lines, a plurality of
10 column-direction wiring lines, insulating layers formed at intersections between the row-direction wiring lines and the column-direction wiring lines, and a plurality of electron-emitting devices connected to the row-direction wiring lines and the column-direction wiring lines, and
15 spacer for maintaining an interval between the electron source and the counter substrate is arranged on some of the row-direction wiring lines among the plurality of row-direction wiring lines, characterized by comprising:

 a means for sequentially turning on the plurality of
20 row-direction wiring lines; and

 a controlled current application means for applying a predetermined controlled current to the plurality of column-direction wiring lines.

[Claim 2]

25 An electron source apparatus which has an electron source and a counter substrate arranged to face the electron

source and in which the electron source has on a substrate
a plurality of row-direction wiring lines, a plurality of
column-direction wiring lines, insulating layers formed at
intersections between the row-direction wiring lines and
5 the column-direction wiring lines, and a plurality of
electron-emitting devices connected to the row-direction
wiring lines and the column-direction wiring lines, and
spacers for maintaining an interval between the electron
source and the counter substrate are arranged at different
10 positions on the plurality of row-direction wiring lines,
characterized by comprising:

a means for sequentially turning on the plurality of
row-direction wiring lines; and

a controlled current application means for applying
15 a predetermined controlled current to the plurality of
column-direction wiring lines.

[Claim 3]

An image forming apparatus comprising the electron
source apparatus and an image forming member for forming
20 an image by irradiation of electrons from the electron source
apparatus,

wherein said image forming member is said counter
substrate of the electron source apparatus according to claim
1 or claim 2.

25 [Detailed Description of the Invention]

[0001]

[Industrial Field of Utilization]

The present invention relates to an electron source apparatus having a plurality of electron-emitting devices wired in a matrix, and an image forming apparatus using the
5 electron source apparatus.

[0002]

[Prior Art]

Conventionally, two types of devices, namely thermionic and cold cathode devices, are known as
10 electron-emitting devices. Known examples of the cold cathode devices are field emission type electron-emitting devices (to be referred to as FE type electron-emitting devices hereinafter), and metal/insulator/metal type
electron-emitting devices (to be referred to as MIM type
15 electron-emitting devices hereinafter). A known example of surface-conduction emission type electron-emitting devices is described in, e.g., M.I. Elinson, "Radio Eng. Electron Phys., 10, 1290 (1965) and other examples will be described later.

20 [0003]

The surface-conduction emission type electron-emitting device utilizes the phenomenon that electrons are emitted by a small-area thin film formed on a substrate by flowing a current in parallel with the film
25 surface. The surface-conduction emission type electron-emitting device includes electron-emitting

devices using an Au thin film [G. Dittmer, "Thin Solid Films", 9,317 (1972)], an $\text{In}_2\text{O}_3/\text{SnO}_2$ thin film [M. Hartwell and C.G. Fonstad, "IEEE Trans. ED Conf.", 519 (1975)], a carbon thin film [Hisashi Araki et al., "Vacuum", Vol. 26, No. 1, 5 p. 22 (1983)], and the like, in addition to an SnO_2 thin film according to Elinson mentioned above.

[0004]

Known examples of the FE type electron-emitting devices are described in W.P. Dyke and W.W. Dolan, "Field 10 emission", Advance in Electron Physics, 8, 89 (1956) and C.A. Spindt, "Physical properties of thin-film field emission cathodes with molybdenum cones", J. Appl. Phys., 47, 5248 (1976).

[0005]

15 As another FE type device structure, there is an example in which an emitter and gate electrode are arranged on a substrate to be almost parallel to the surface of the substrate.

[0006]

20 A known example of the MIM type electron-emitting devices is described in C.A. Mead, "Operation of tunnel emission Devices", J. Appl. Phys., 32,646 (1961).

[0007]

Since the above-described cold cathode devices can 25 emit electrons at a temperature lower than that for thermionic cathode devices, they do not require any heater.

The cold cathode device has a structure simpler than that of the thermionic cathode device and can shrink in feature size. Even if a large number of devices are arranged on a substrate at a high density, problems such as heat fusion
5 of the substrate hardly arise. In addition, the response speed of the cold cathode device is high, while the response speed of the thermionic cathode device is low because thermionic cathode device operates upon heating by a heater.
[0008]

10 For this reason, applications of the cold cathode devices have enthusiastically been studied.
[0009]

Of cold cathode devices, the surface-conduction emission type electron-emitting devices have a simple
15 structure and can be easily manufactured, so that many devices can be formed on a wide area. As disclosed in Japanese Patent Laid-Open No. 64-31332 filed by the present applicant, a method of arranging and driving many devices has been studied.

20 [0010]

Regarding applications of the surface-conduction emission type electron-emitting devices, e.g., image forming apparatuses such as an image display apparatus and image recording apparatus, charge beam sources, and the like
25 have been studied.

[0011]

Particularly as an application to image display apparatuses, as disclosed in the USP 5,066,883 and Japanese Patent Laid-Open Nos. 2-257551 and 4-28137 filed by the present applicant, an image display apparatus using a combination of a surface-conduction emission type electron-emitting device and a fluorescent substance which emits light upon irradiation with an electron beam has been studied. This type of image display apparatus using a combination of the surface-conduction emission type electron-emitting device and fluorescent substance is expected to exhibit more excellent characteristics than other conventional image display apparatuses. For example, compared to recent popular liquid crystal display apparatuses, the above display apparatus is superior in that it does not require any backlight because of self-emission type and that it has a wide view angle.

[0012]

A method of driving a plurality of FE type electron-emitting devices arranged side by side is disclosed in, e.g., USP 4,904,895 filed by the present applicant. A known application of FE type electron-emitting devices to an image display apparatus is a flat panel display apparatus reported by R. Meyer et al. [R. Meyer: "Recent Development on Microtips Display at LETI", Tech. Digest of 4th Int. Vacuum Microelectronics Conf., Nagahara, pp. 6 - 9 (1991)]. An application of many MIM type electron-emitting devices

arranged side by side to an image display apparatus is disclosed in Japanese Patent Laid-Open No. 3-55738 filed by the present applicant.

[0013]

5 Fig. 14 shows an example of a multi electron source wiring method. In the electron source shown in Fig. 14, m cold cathode devices in the vertical direction and n cold cathode devices in the horizontal direction, i.e., a total of $n \times m$ cold cathode devices are two-dimensionally arrayed
10 in a matrix. In Fig. 14, reference numeral 3074 denotes a cold cathode device; 3072, a row-direction wiring line; 3073, a column-direction wiring line; 3075, a wiring resistance of the row-direction wiring line; and 3076, a wiring resistance of the column-direction wiring line.
15 Reference symbols Dx_1, Dx_2, \dots, Dx_m denote feeding terminals of the row-direction wiring lines; and Dy_1, Dy_2, \dots, Dy_n , feeding terminals of the column-direction wiring lines. This simple wiring method is called a matrix wiring method. The matrix wiring method can easily manufacture a multi
20 electron source because of a simple structure.

[0014]

When a multi electron beam by the matrix wiring method is to be applied to an image forming apparatus, m and n must be several hundreds or more in order to ensure the display
25 capacitance. Further, a cold cathode device must accurately output an electron beam with a desired intensity

in order to display an image at an accurate luminance.

[0015]

When many cold cathode devices wired in a matrix are to be driven, devices of one row of the matrix are
5 simultaneously driven. The row to be driven is sequentially switched to scan all the rows. According to this method, the driving time assigned each device is ensured n times longer than in a method of sequentially scanning all the devices one by one. Thus, the luminance of the display
10 apparatus can be increased.

[0016]

More specifically, there are proposed an arrangement in which a voltage source is connected to matrix wiring to drive devices, and a method of driving FE type devices using
15 a controlled constant current source, as disclosed in USP 5,300,862 to Parker et al. Fig. 15 is a circuit diagram for explaining this.

[0017]

In USP 5,300,862, the X direction shown in Fig. 15
20 is a row direction, and the Y direction is a column direction. In the following description, however, the X direction is defined as a column direction, and the Y direction is defined as a row direction in order to match the description of the present invention.

25 [0018]

In Fig. 15, reference numerals 2201a, 2201b, and 2201c

denote controlled constant current sources; 2202, a switching circuit; 2203, a voltage source; 2204a, column wiring lines; 2204b, row wiring lines; and 2205, FE type devices.

5 [0019]

The switching circuit 2202 selects one of the row wiring lines 2204b, and connects it to the voltage source 2203. The controlled constant current sources 2201a, 2201b, and 2201c supply currents to the respective column wiring
10 lines 2204a. These operations are properly performed in synchronism with each other to drive FE type devices of one row.

[0020]

[Problems That the Invention Is to Solve]

15 In an electron source apparatus, few substances desirably exist in the space between an electron source and a counter substrate facing the electron source. However, if substances present in the space are reduced to be smaller in number than substances present in an atmosphere outside
20 the apparatus, the compression pressure is generated to the electron source apparatus. To prevent this, there is known an arrangement in which spacers are interposed between the electron source and the counter substrate in the electron source apparatus. There is also known an arrangement in
25 which spacers are arranged on the wiring lines of the electron source. The arrangement in which spacers are arranged on

the wiring lines of the electron source is desirable as an arrangement using spacers. However, the inventor of the present application has found that arranging spacers on wiring lines varies the electron emission state from
5 electron-emitting devices.

[0021]

Further, the inventor of the present application has found that the variations become more typical when the following arrangements (1) to (4) are employed:

10 (1) In the electron source, a plurality of wiring lines are laid out in a matrix, and electron-emitting devices are formed at or near the intersections of the matrix.

(2) One of row-direction wiring lines of matrix wiring is selected, and signals are supplied from column-direction
15 wiring lines to a plurality of electron-emitting devices connected to the selected row-direction wiring line to drive the devices.

(3) In arrangement (2), the electron-emitting device is an electron-emitting device in which when the device
20 receives different potentials from two wiring lines (row-direction wiring line and column-direction wiring line), a current amount flowing between the two wiring lines (row-direction wiring line and column-direction wiring line) connected to the device is relatively larger than an
25 emitted current amount.

(4) The spacer is conductive (conductivity of the

spacer is high).

[0022]

The inventor of the present application has made extensive studies to find out that the found phenomena occur
5 when spacers are arranged on some of wiring lines among a plurality of wiring lines, or spacers are arranged at different positions on wiring lines, the resistance value of an electrical path extending from a driving circuit to an electron-emitting device is influenced by the presence
10 of the spacer in driving the electron-emitting device via a wiring line.

[0023]

The present invention has been made in consideration of the above situation, and provides an electron source
15 apparatus and an image forming apparatus capable of suppressing variances in the electron emission state from electron-emitting devices.

[0024]

[Means of solving the Problems]

20 In order to achieve the above purpose, an electron source apparatus according to the present application has an electron source and a counter substrate arranged to face the electron source and the electron source has on a substrate a plurality of row-direction wiring lines, a plurality of
25 column-direction wiring lines, insulating layers formed at intersections between the row-direction wiring lines and

the column-direction wiring lines, and a plurality of electron-emitting devices connected to the row-direction wiring lines and the column-direction wiring lines, and spacer for maintaining an interval between the electron
5 source and the counter substrate is arranged on some of the row-direction wiring lines among the plurality of row-direction wiring lines is characterized by comprising:

a means for sequentially turning on the plurality of row-direction wiring lines; and

10 a controlled current application means for applying a predetermined controlled current to the plurality of column-direction wiring lines.

[0025]

According to the electron source apparatus of the
15 present invention described above, the controlled current application means can be used to suppress variations in current applied to electron-emitting devices and suppress variations in electron emission state from the electron-emitting devices even when the resistance value
20 of an electrical path extending from a driving circuit to an electron-emitting device is influenced by an arrangement of spacers.

[0026]

Here, the ON state of the row-direction wiring line
25 is a state in which a selected row-direction wiring line receives a potential different from a potential to an

unselected row-direction wiring line, and an electron-emitting device connected to the selected row-direction wiring line can emit electrons in cooperation with control from a column-direction wiring line.

5 [0027]

An electron source apparatus according to the present application has an electron source and a counter substrate arranged to face the electron source and in which the electron source has on a substrate a plurality of row-direction wiring
10 lines, a plurality of column-direction wiring lines, insulating layers formed at intersections between the row-direction wiring lines and the column-direction wiring lines, and a plurality of electron-emitting devices connected to the row-direction wiring lines and the
15 column-direction wiring lines, and spacers for maintaining an interval between the electron source and the counter substrate are arranged at different positions on the plurality of row-direction wiring lines is characterized by comprising:

20 a means for sequentially turning on the plurality of row-direction wiring lines; and

a controlled current application means for applying a predetermined controlled current to the plurality of column-direction wiring lines.

25 [0028]

By virtue of this, since the variance of current applied to the electron-emitting devices can be suppressed by the controlled current application means, it is possible to suppress variances in the electron emission state from
5 electron-emitting devices and to provide an electron source apparatus capable of driving suitably without arranging spacers at the same position of all of wirings.

[0029]

The image forming apparatus of the present invention
10 is an image forming apparatus comprising the electron source apparatus and an image forming member for forming an image by irradiation of electrons from the electron source apparatus, where the image forming member is the counter substrate of the electron source apparatus of the present
15 invention.

[0030]

[Embodiments]

Hereafter, the embodiment of this invention will be described while referring to the accompanying drawings.

20 [0031]

Figs. 1 and 2 are schematic plan views showing an embodiment of an electron source apparatus according to the present invention. The electron source apparatus of this embodiment uses a surface-conduction emission type
25 electron-emitting device, but the present invention can also be suitably applied to another type of cold cathode

electron-emitting device such as an FE type or MIM type device.
For descriptive convenience, Figs. 1 and 2 show an electron
source apparatus having $4 \times 3 = 12$ electron-emitting devices.
In practice, in the electron source apparatus of this
5 embodiment, 500 devices in the row direction and 1,500
devices in the column direction are arrayed in a matrix.
[0032]

As shown in Figs. 1 and 2, each electron-emitting
device of the electron source apparatus is connected to a
10 row-direction wiring line 8 and column-direction wiring line
6. Spacers 9 are arranged on some of the row-direction wiring
lines 8. In an example shown in Fig. 1, the spacers 9 are
arranged at identical positions on the row-direction wiring
lines 8 on which the spacers 9 are arranged. As shown in
15 Fig. 2, the spacers 9 may be arranged at different positions
on the row-direction wiring lines 8 on which the spacers
9 are arranged. "The spacers 9 are arranged at different
positions on the row-direction wiring lines 8" means an
arrangement in which the distance from an intersection with
20 the same column-direction wiring line 6 to the spacer 9 on
each row-direction wiring line 8 is changed, or the spacers
9 different in size are arranged on the respective
row-direction wiring lines 8.

[0033]

25 The respective column-direction wiring lines 6 are
connected to controlled constant current sources 221a, 221b,

and 221c serving as controlled current application means. The controlled constant current source is a current source capable of outputting a desired current value.

[0034]

5 The respective row-direction wiring lines 8 are connected to a voltage application means made up of a switching circuit and voltage source. As shown in Fig. 1, the switching circuit and voltage source may be constituted by a voltage source 223 and a switching circuit 222 for
10 selecting the row-direction wiring lines 8 while sequentially scanning them. As shown in Fig. 2, the switching circuit and voltage source may adopt two voltage sources 224 and 225, and apply a predetermined potential to row-direction wiring lines 8 other than a row-direction
15 wiring line 8 selected by the switching circuit 222.

[0035]

The arrangement shown in Fig. 2 can prevent unselected row-direction wiring lines 8 from floating, can also control a leakage current, and can be used more preferably than the
20 arrangement shown in Fig. 1.

[0036]

The electron source apparatus of the present invention will be explained in more detail.

[0037]

25 [Embodiment]

This embodiment will exemplify the steps in forming

an electron source apparatus using a surface-conduction emission type electron-emitting device, and an image forming apparatus using the electron source apparatus.

[0038]

5 The steps in forming an electron source apparatus according to this embodiment will be described with reference to Figs. 3 to 5. Fig. 3 shows sectional views of the steps in forming the electron source apparatus shown in Fig. 1 and the like. Figs. 4 and 5 show plan views of the steps
10 in forming the electron source apparatus shown in Fig. 1 and the like. In Figs. 4 and 5, the electron source apparatus has nine electron-emitting devices for descriptive convenience.

[0039]

15 Step 1: An SiO_2 layer was formed to a thickness of $0.5 \mu\text{m}$ on one major surface of soda-lime glass by sputtering, thereby obtaining a substrate 1.

[0040]

As shown in Figs. 4(a) and 3(a), 500 x 1,500 pairs
20 of device electrodes 2 and 3 were formed. Formation of the device electrodes 2 and 3 used offset printing. More specifically, organic Pt paste containing Pt was applied to an intaglio plate having recesses corresponding to the pattern of the device electrodes 2 and 3, and this paste
25 was transferred to the substrate 1. The transferred ink was heated and calcined to form device electrodes 2 and 3.

[0041]

Step 2: As shown in Fig. 4(b), column-direction wiring lines 6 (also called X-direction wiring lines or lower wiring lines) were formed to be connected to the device electrodes 2 each of which was one of the device electrodes. Formation of the column-direction wiring lines 6 used screen printing. More specifically, Ag paste was printed on the substrate 1 via a screen plate having openings corresponding to the pattern of the column-direction wiring lines 6, and the printed paste was heated and calcined to form Ag column-direction wiring lines 6.

[0042]

Step 3: As shown in Fig. 4(c), interlevel insulating layers 7 were formed at intersections between the column-direction wiring lines 6 and row-direction wiring lines 8. Formation of the interlevel insulating layers 7 used screen printing. As shown in Fig. 4(c), the shape of the interlevel insulating layer 7 was a comb finger shape which covered the intersection between the column-direction wiring line 6 and the row-direction wiring line 8, and had a recess at which the row-direction wiring line 8 and the device electrode 3 could be connected to each other. More specifically, glass paste which mainly contained lead oxide and was prepared by mixing a glass binder and resin was printed on the substrate 1, and the printed paste was heated and calcined to form interlevel insulating layers 7.

[0043]

Step 4: As shown in Fig. 5(a), row-direction wiring lines 8 (also called Y-direction wiring lines or upper wiring lines) were formed to be connected to the device electrodes 3 each of which was one of the device electrodes. Formation of the row-direction wiring lines 8 employed screen printing. More specifically, Ag paste was printed on the substrate 1 via a screen plate having openings corresponding to the pattern of the row-direction wiring lines 8, and the printed paste was heated and calcined to form Ag row-direction wiring lines 8.

[0044]

Step 5: An unevaporative getter (not shown) was applied on each row-direction wiring line 8 via a mask by a reduced-pressure plasma spraying method. The getter material was a Zr-Fe-V alloy.

[0045]

Step 6: As shown in Figs. 3(b) and 5(b), conductive films 4 were formed to connect the device electrodes 2 and 3. Formation of the conductive films 4 used a bubble-jet method as one of ink-jet methods. More specifically, droplets of an aqueous solution of 0.15% of a Pd organic metal compound, 15% of isopropyl alcohol, 1% of ethylene glycol, and 0.05% of polyvinyl alcohol were applied between the device electrodes 2 and 3 by the ink-jet method.

[0046]

Subsequently, the droplets were calcined in the atmosphere at 350°C to form PdO conductive films 4. The PdO film thickness was about 15 nm. Although this embodiment adopted the ink-jet method, formation of the conductive films 4 can use another method such as sputtering.

[0047]

By these steps, an electron source substrate before forming processing was formed.

[0048]

10 Step 7: The electron source substrate 1 before forming processing was placed in a chamber (not shown), and the interior of the chamber was evacuated to about 10^{-5} [Torr].

[0049]

As shown in Fig. 3(c), electrification forming processing was executed via the column-direction wiring lines 6 and row-direction wiring lines 8 to form gaps 11 in part of the conductive films 4. The maximum voltage applied in the forming step was 5.1 V.

[0050]

20 Then, electrification activation processing was done to form carbon films 10 in the gaps 11 formed by forming processing and on the conductive films 4 near the gaps, thereby forming electron-emitting portions 5. In the electrification activation step, an organic gas
25 (benzonitrile) was introduced into the chamber to 10^{-4} [Torr], and brought into contact with the gaps 11. In this state,

a constant voltage pulse of 15 V was applied to the conductive films 4 via the column-direction wiring lines 6 and row-direction wiring lines 8.

[0051]

5 Step 8: While the chamber and electron source substrate 1 were heated, the interior of the chamber was evacuated until the internal pressure of the chamber reached 10^{-10} [Torr].

[0052]

10 By these steps, the electron source substrate 1 was formed.

[0053]

 Spacers 9 were arranged on the electron source substrate. A counter substrate on which Al was deposited
15 as an accelerating electrode for accelerating electrons from the fluorescent substances and electron source was integrated with the electron source substrate to complete an image forming apparatus shown in Fig. 6.

[0054]

20 In this embodiment, the spacer was constituted such that electrodes were formed at the ends of a glass substrate (end in contact with the wiring side on the electron source substrate and end in contact with the accelerating electrode of the counter substrate), and a conductive film was formed
25 on the entire surface of the glass substrate to suppress charge-up of the spacer.

[0055]

Fig. 6 is a partially cutaway perspective view of the display panel (image forming apparatus) used in this embodiment showing the internal structure of the display panel.

[0056]

In Fig. 6, reference numeral 1 denotes the electron source substrate (rear plate); 1006, a side wall; and 1007, a face plate. The electron source substrate 1, side wall 1006, and face plate 1007 serving as a counter substrate constitute an airtight container for keeping the interior of the display panel vacuum. To construct the airtight container, the electron source substrate 1, side wall 1006, and face plate 1007 must be sealed to obtain sufficient strength and maintain airtight condition at the joint portions of the respective members. For example, frit glass was applied to the joint portions, and calcined in the atmosphere or nitrogen atmosphere to seal the members. A method of evacuating the interior of the airtight container will be described later.

[0057]

A fluorescent film 1008 is formed on lower surface of the face plate 1007. Since this embodiment relates to a color display apparatus, the fluorescent film 1008 is coated with fluorescent substances of red (R), green (G), and blue (B), i.e., three primary colors used in the CRT

field. As shown in Fig. 7, fluorescent substances of the respective colors are formed into stripes, and black members 1010 are formed between the stripes of the fluorescent substances. The purposes of forming the black members 1010 are to prevent display color misregistration even if the irradiation position of an electron beam is shifted to some extent, and to prevent degradation of display contrast by shutting off reflection of external light. The black members 1010 are formed from graphite as a main component, but may be formed from another material so long as the above purpose is attained.

[0058]

The coating pattern of the fluorescent substances of the three primary colors is not limited to stripes shown in Fig. 7, but may be a delta pattern as shown in Fig. 8 or another pattern.

[0059]

Note that when a monochrome display panel is to be formed, fluorescent substances of a single color may be used as the fluorescent substances 1008, and the black member need not always be used.

[0060]

A metal back 1009, which is well-known in the CRT field, is formed on the fluorescent film 1008 on the rear plate side. The purposes of forming the metal back 1009 are to improve the light utilization ratio by mirror-reflecting

part of the light emitted by the fluorescent film 1008, to protect the fluorescent film 1008 from collision with negative ions, to use the metal back 1009 as an electrode for applying an electron beam accelerating voltage of, e.g.,
5 10 kV, to use the metal back 1009 as a conductive path of electrons which excited the fluorescent film 1008, and the like. The metal back 1009 was formed by forming the fluorescent film 1008 on the face plate substrate 1007, smoothing the surface of the fluorescent film, and depositing
10 aluminum on the smoothed surface by vacuum deposition.
[0061]

To apply an accelerating voltage or improve the conductivity of the fluorescent film, e.g., ITO transparent electrodes may be formed between the face plate substrate
15 1007 and the fluorescent film 1008 though these electrodes were not used in this embodiment.
[0062]

Reference symbols Dx1 to Dxm and Dyl to Dyn and Hv denote feeding terminals of an airtight structure in order
20 to electrically connect the display panel to an electric circuit. Dx1 to Dxm are electrically connected to the row-direction wiring lines 8 of the electron source; Dyl to Dyn, to the column-direction wiring lines 6 of the electron source; and Hv, to the metal back 1009 of the face plate.
25 [0063]

To evacuate the interior of the airtight container,

an exhaust pipe and vacuum pump (neither is shown) were connected after the airtight container was assembled, and the airtight container was evacuated to a vacuum of about 10^{-7} [Torr]. Then, the vacuum pump was shut.

5 [0064]

The electron source, image display apparatus, and driving method therefor in this embodiment will be explained in detail.

[0065]

10 The image forming apparatus (display panel 101) formed in the above-described steps was connected to a circuit shown in Fig. 9.

[0066]

In Fig. 9, the display panel 101 is connected to an
15 external circuit via the terminals Dx1 to Dxm ($m = 500$) and the terminals Dyl to Dyn ($n = 1,500$). The high-voltage terminal Hv on the face plate is connected to an external high-voltage power supply Va to accelerate emitted electrons. The terminals Dx1 to Dxm receive scan signals for
20 sequentially driving the multi electron beam source formed in the above-described panel, i.e., the surface-conduction emission type electron-emitting devices wired in a matrix of 500 rows and 1,500 columns in units of rows. The terminals Dyl to Dyn receive modulation signals for controlling
25 electron beams output from the respective surface-conduction emission type electron-emitting devices

on one row selected by the scan signal.

[0067]

A scan circuit 102 will be explained. This circuit incorporates 500 switching elements. On the basis of a control signal Tscan generated by a control circuit 103, each switching element connects a DC power supply Vx1 to the wring terminal of a scanned electron-emitting device row, and a DC power supply Vx2 to the terminal of an unscanned electron-emitting device row. Each switching element can be easily formed from a switching element such as an FET. The output voltages of Vx1 and Vx2 will be described later.

[0068]

The control circuit 103 matches the operation timings of respective circuits so as to attain proper display based on an externally input image signal. The externally input image signal includes a composite signal of image data and a sync signal, like an NTSC signal, or image data and a sync signal which are separated in advance. In this embodiment, the latter signal will be described. (Note that the former image signal can also be processed as follows by adopting a well-known sync separation circuit and separating image data and a sync signal from each other.)

[0069]

More specifically, the control circuit 103 generates control signals Tscan and Tmry on the basis of the externally input sync signal Tsync. In general, the sync signal

includes a vertical sync signal and horizontal sync signal. In this case, however, the sync signal is represented by Tsync for descriptive convenience.

[0070]

5 Externally input image signal (luminance data) is input to a shift register 104. The shift register 104 serial/parallel-converts in units of lines of an image the image data serially input in time-series. The shift register 104 operates on the basis of the control signal
10 (shift signal) Tsft input from the control circuit 103. Data of one line of another parallel-converted image (corresponding to driving data of N electron-emitting devices) are output as parallel signals Id1 to Idn to a latch circuit 105.

15 [0071]

The latch circuit 105 is a memory circuit for storing data of one line of an image for a necessary time, and simultaneously stores Id1 to Idn in accordance with a control signal Tmry sent from the control circuit 103. The stored
20 data are output as I'd1 to I'dn to a voltage modulation circuit 106.

[0072]

The voltage modulation circuit 106 outputs, as I"d1 to I"dn, voltage signals whose amplitudes are modulated in
25 accordance with the image data I'd1 to I'dn. More specifically, the voltage modulation circuit 106 outputs

a voltage pulse having a larger amplitude for a higher luminance level of image data. For example, the voltage modulation circuit 106 outputs a voltage of 2 [V] for the maximum luminance, and a voltage of 0 [V] for the minimum
5 luminance. The output signals I^{*d1} to I^{*dn} are input to a voltage/current conversion circuit 107.

[0073]

The voltage/current conversion circuit 107 is a circuit (controlled current application means) for
10 controlling a current to be flowed through a surface-conduction emission type electron-emitting device in accordance with the amplitude of an input voltage signal. An output signal from the circuit 107 is applied to the terminals $Dy1$ to Dyn of the display panel 101.

15 [0074]

Fig. 10 is a view showing the internal arrangement of the voltage/current conversion circuit 107 shown in Fig. 9. As shown in Fig. 10, the voltage/current conversion circuit 107 incorporates voltage/current converters 301 in
20 correspondence with the input signals I^{*d1} to I^{*dn} .

[0075]

Each voltage/current converter 301 is constituted by a circuit as shown in Fig. 11. In Fig. 11, reference numeral 302 denotes an operational amplifier; 303, e.g., a junction
25 FET type transistor; and 304, a resistor of $R [\Omega]$. The circuit in Fig. 11 determines the magnitude of a current

Iout to be output in accordance with the amplitude of an input voltage signal Vin. This current Iout satisfies

$$I_{out} = V_{in}/R \quad \dots(1)$$

[0076]

5 By setting the design parameter of the voltage/current converter 301 to a proper value, the current Iout to be flowed through a surface-conduction emission type electron-emitting device can be controlled in accordance with the voltage-modulated image data Vin.

10 [0077]

 In this embodiment, a resistance R of the resistor 304 and another design parameter are determined as follows.

[0078]

 That is, the surface-conduction emission type
15 electron-emitting device used in this embodiment has an electron emission characteristic having $V_{th} = 8$ [V] as a threshold voltage, as shown in Fig. 12. To prevent unwanted emission of the display screen, a voltage applied to an unscanned electron-emitting device row must necessarily be
20 lower than 8 [V]. Since the scan circuit 102 in Fig. 9 applies the output voltage of the voltage source Vx2 to the row-direction wiring line of an unscanned electron-emitting device row, the voltage source Vx2 must satisfy

$$V_{x2} < 8 \quad \dots(2)$$

25 For this purpose, this embodiment defined the voltage of Vx2 to 7.5 [V]. Hence, the voltage applied to an unscanned

electron-emitting device does not exceed 7.5 [V] at maximum.

[0079]

An electron-emitting device during scanning must appropriately emit an electron beam in accordance with image data. In this embodiment, an emission current I_e was controlled by properly modulating a device current I_f using the I_f - I_e characteristic of the surface-conduction emission type electron-emitting device shown in Fig. 13. As shown in Fig. 13, an emission current in causing the display apparatus to emit light at the maximum luminance was set to $I_{e\max}$, and the device current at this time was set to $I_{f\max}$. For example, $I_{e\max} = 0.6 [\mu A]$, and $I_{f\max} = 0.8 [mA]$.
[0080]

The voltage V_{in} of an output signal from the voltage modulation circuit 106 is 2 [V] for the maximum luminance and 0 [V] for the minimum luminance, and is substituted into equation (1) to determine the resistance R to

$$R = 2/0.0008 = 2.5 [k\Omega].$$

[0081]

In emitting light at the maximum luminance, the surface-conduction emission type electron-emitting device has an electrical resistance:

$$12 [V]/0.8 [mA] = 15 [k\Omega]$$

Considering that this surface-conduction emission type electron-emitting device was series-connected to the resistance $R (= 2.5 [k\Omega])$, the output voltage of the voltage

source V_{x1} was set to

$$V_{x1} = 15 \text{ [V]}$$

[0082]

An accelerating voltage V_a applied to fluorescent
5 substances was determined as follows. That is, application
power to fluorescent substances necessary for obtaining a
desired maximum luminance was calculated from the emission
efficiency of fluorescent substances, and the magnitude of
the accelerating voltage V_a was determined to 10 [kV] so
10 as to set ($I_{\text{emax}} \times V_a$) to satisfy the application power.

[0083]

In this way, the parameters were set.

[0084]

As described above, this embodiment used the
15 relationship between the device current I_f and emission
current I_e of the surface-conduction emission type
electron-emitting device shown in Fig. 13. The device
current I_f was modulated in accordance with image data to
control the emission current I_e and attain gray-level
20 display.

[0085]

When no controlled constant current source was used,
the current I_f applied to the surface-conduction emission
type electron-emitting device varied, and luminance
25 faithful to image data was not reproduced. When a controlled
constant current source was used, like this embodiment, the

luminance did not vary, and no color misregistration occurred.

[0086]

Since V_{x2} was applied to an unselected row, and the
5 voltage/current conversion circuit 107 modulated the device
current I_f flowing through the surface-conduction emission
type electron-emitting device, the leakage current could
be kept constant, and an image could be displayed on the
entire display screen at a luminance faithful to an original
10 image signal.

[0087]

This embodiment has described an arrangement shown
in Fig. 10 as an embodiment of the voltage/current conversion
circuit 107. However, the circuit arrangement is not
15 limited to this as far as the voltage/current conversion
circuit 107 can modulate a current flowing through a load
resistor (surface-conduction emission type
electron-emitting device) in accordance with an input
voltage. For example, when a relative large output current
20 I_{out} is required, a power transistor is desirably
Darlington-connected to the transistor 303.

[0088]

This embodiment uses as an input video signal a digital
video signal which can easily undergo data processing.
25 However, this is not limited to a digital video signal, and
may be an analog video signal.

[0089]

This embodiment adopts for serial/parallel conversion processing the shift register 104 which can easily process a digital signal. However, the present invention is not limited to this, and may use a random access memory having a function equivalent to the shift register by controlling a storage address and sequentially changing the storage address.

[0090]

As described above, this embodiment could suppress variations in voltage effectively applied to a device. Accordingly, a high-quality image almost free from a luminance distribution could be formed.

[0091]

[Effect of the Invention]

As has been described above, the present invention comprises a means for sequentially turning on a plurality of row-direction wiring lines, and a controlled current application means for applying a predetermined controlled current to a plurality of column-direction wiring lines. Since the current application means suppresses generation of variations in current applied to electron-emitting devices, this can suppress generation of variations in electron emission state from the electron-emitting devices.

[Brief Description of the Drawings]

[Fig. 1]

Fig. 1 is a schematic plan view showing an embodiment of an electron source apparatus according to the present invention.

[Fig. 2]

5 Fig. 2 is a schematic plan view showing another embodiment of an electron source apparatus according to the present invention.

[Fig. 3]

Fig. 3 shows sectional views of the steps in forming the electron source apparatus shown in Fig. 1 and the like.

[Fig. 4]

Fig. 4 shows plan views of the steps in forming the electron source apparatus shown in Fig. 1 and the like.

[Fig. 5]

15 Fig. 5 shows plan views of the steps in forming the electron source apparatus shown in Fig. 1 and the like.

[Fig. 6]

Fig. 6 is a perspective view showing a display panel (image forming apparatus) according to this embodiment.

20 [Fig. 7]

Fig. 7 is a view showing the coating pattern of fluorescent substances in the fluorescent film of the display panel (image forming apparatus) shown in Fig. 6.

[Fig. 8]

25 Fig. 8 is a view showing another coating pattern of fluorescent substances in the fluorescent film of the display

panel (image forming apparatus) shown in Fig. 6.

[Fig. 9]

Fig. 9 is a block diagram showing the driving circuit of the display panel (image forming apparatus) shown in
5 Fig. 6.

[Fig. 10]

Fig. 10 is a view showing the internal arrangement of a voltage/current conversion circuit shown in Fig. 9.

[Fig. 11]

10 Fig. 11 is a circuit diagram showing a voltage/current converter shown in Fig. 10.

[Fig. 12]

Fig. 12 is a graph showing the electron emission characteristic of an electron-emitting device in the display
15 panel (image forming apparatus) shown in Fig. 6.

[Fig. 13]

Fig. 13 is a graph showing the correlation between an emission current I_e and device current I_f of the electron-emitting device in the display panel (image forming
20 apparatus) shown in Fig. 6.

[Fig. 14]

Fig. 14 is a circuit diagram showing matrix wiring in a conventional electron source apparatus.

[Fig. 15]

25 Fig. 15 is a schematic view showing a conventional electron source apparatus using an FE type device.

[Explanation of the Numerals]

- 1 substrate
- 2,3 device electrodes
- 4 conductive film
- 5 5 electron-emitting portion
- 6 column-direction wiring line
- 7 interlevel insulating layer
- 8 row-direction wiring line
- 9 spacer
- 10 10 carbon film
- 11 gap
- 101 display panel
- 102 scan circuit
- 103 control circuit
- 15 104 shift register
- 105 latch circuit
- 106 voltage modulation circuit
- 107 voltage/current conversion circuit
- 221a,221b,221c constant current sources
- 20 222 switching circuit
- 223,224,225 voltage source
- 301 voltage/current converter
- 302 operational amplifier
- 303 transistor
- 25 304 resistor
- 1006 side wall

1007 face plate

1008 fluorescent film

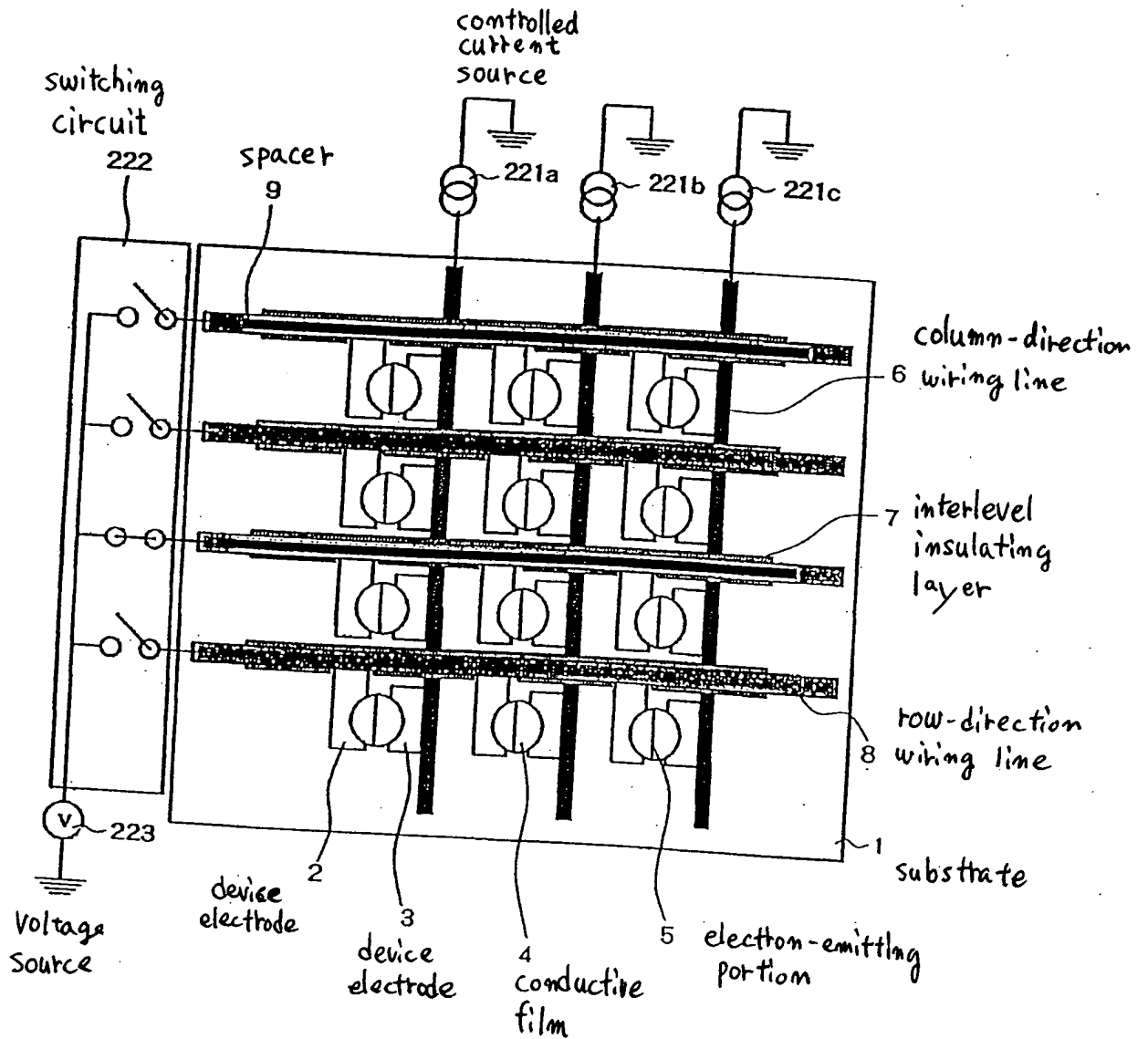
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1010 black members

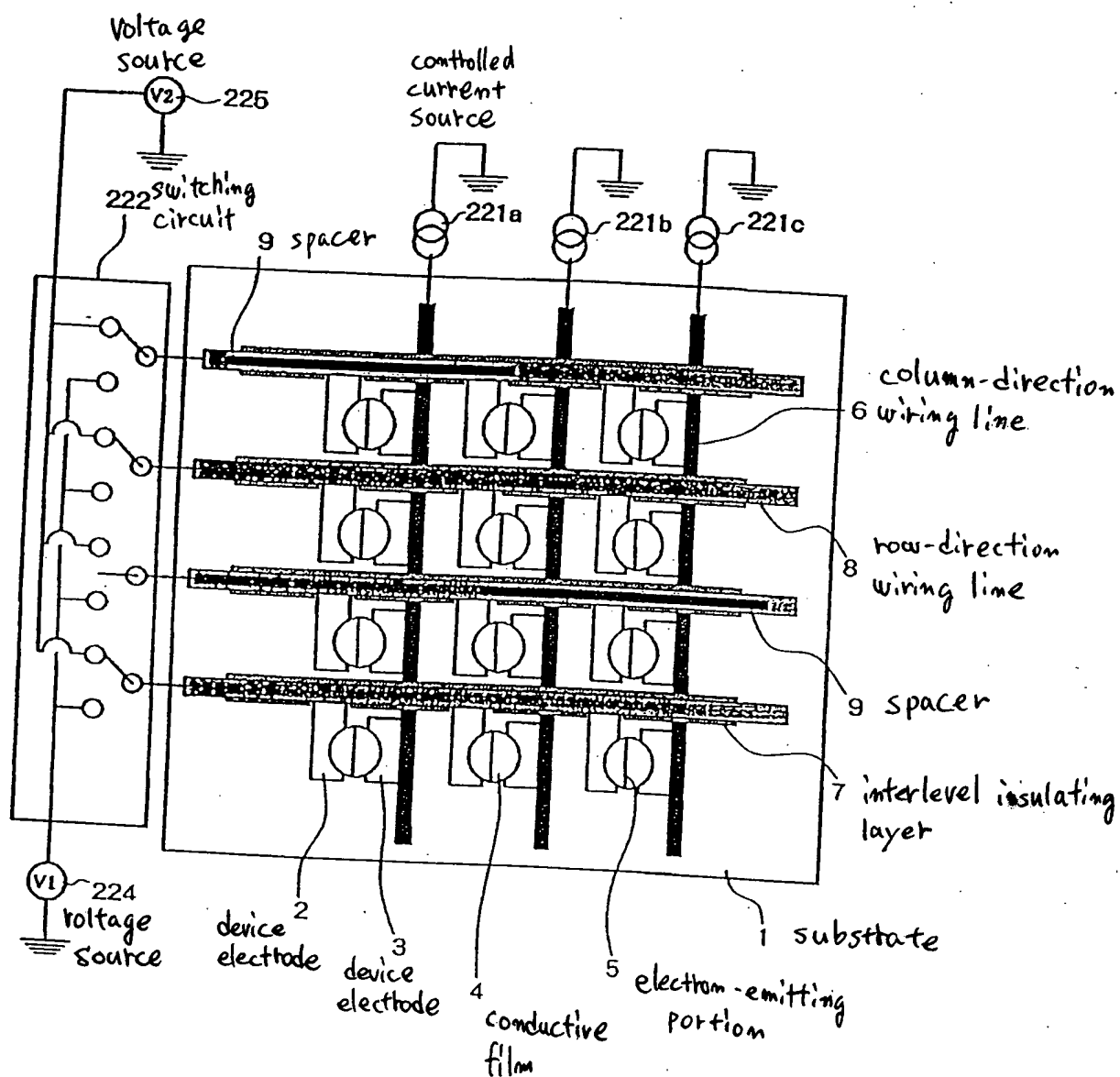
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【Type of the Document】 Drawings.

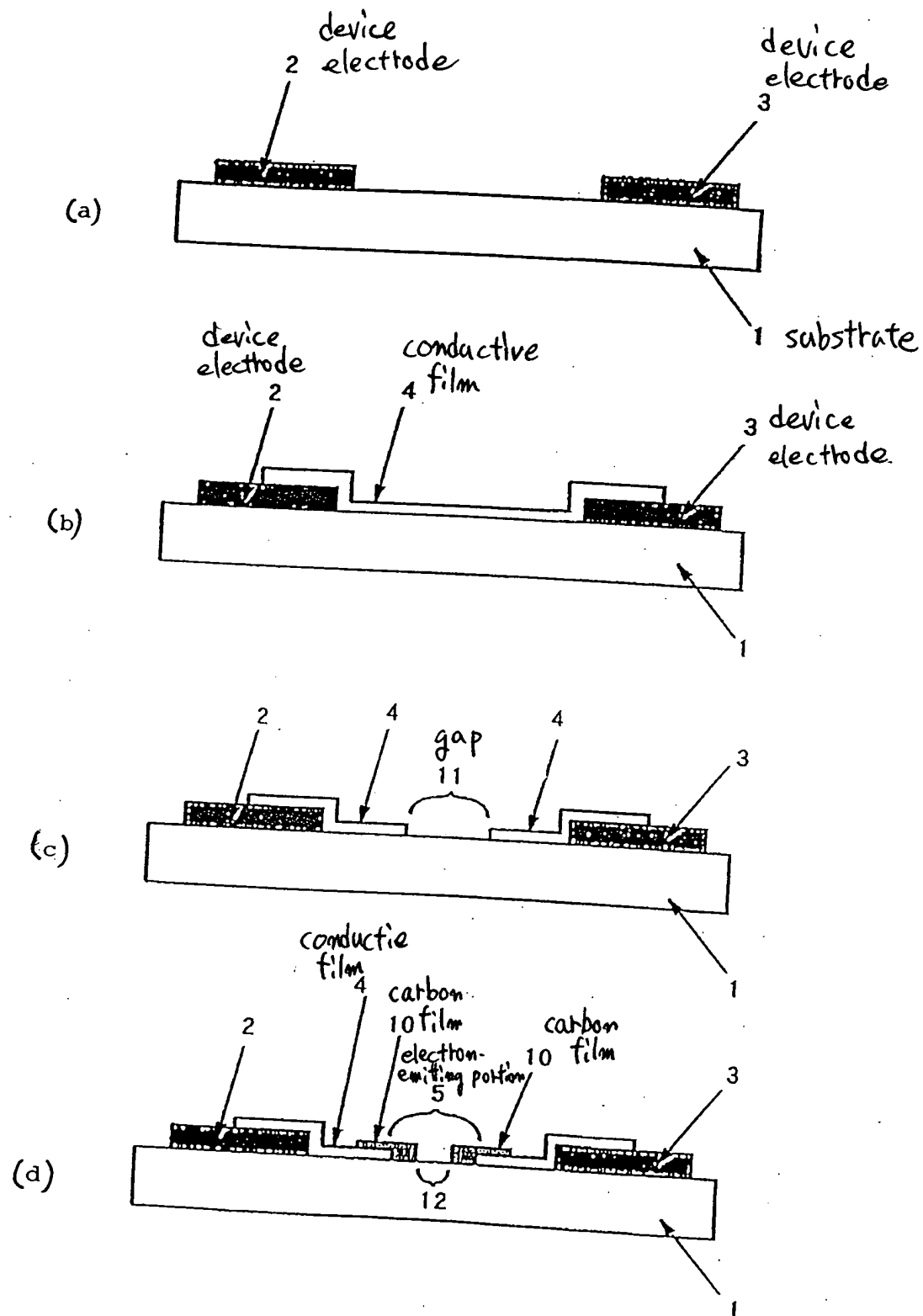
【Fig. 1】



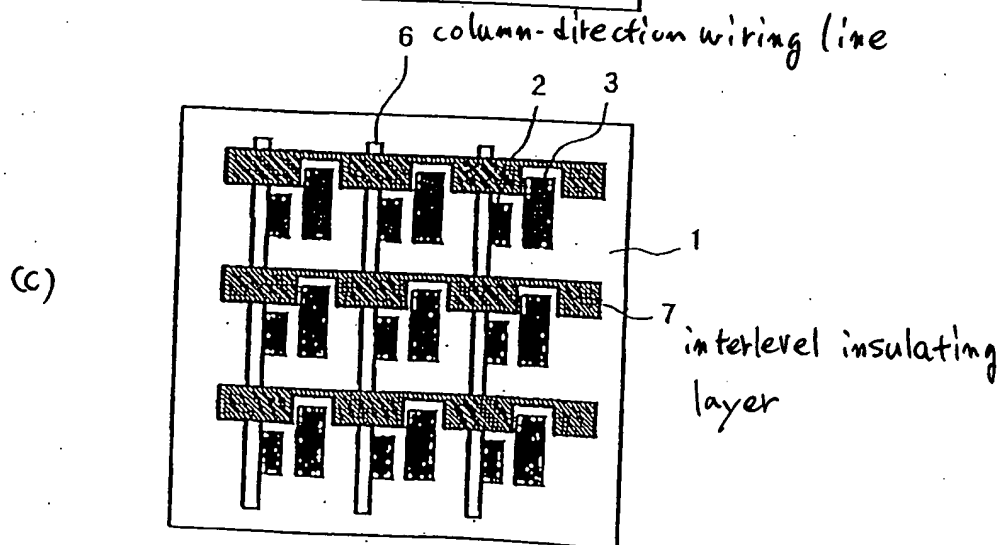
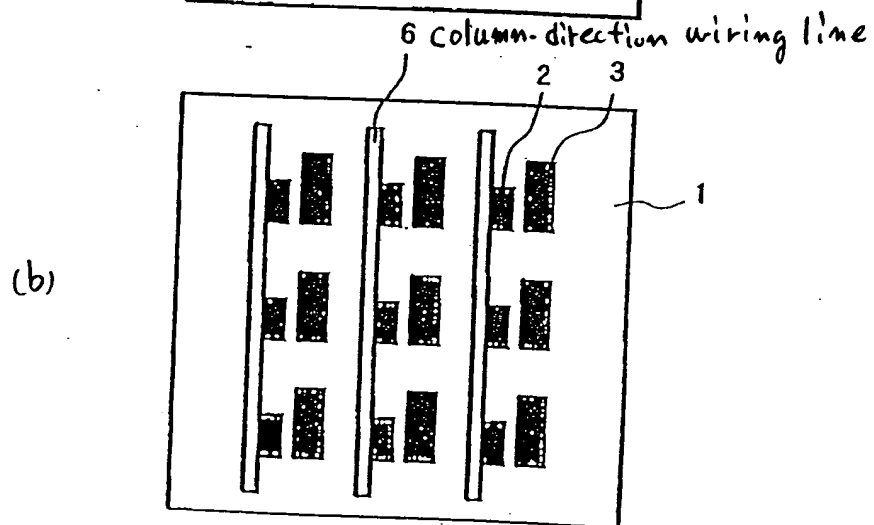
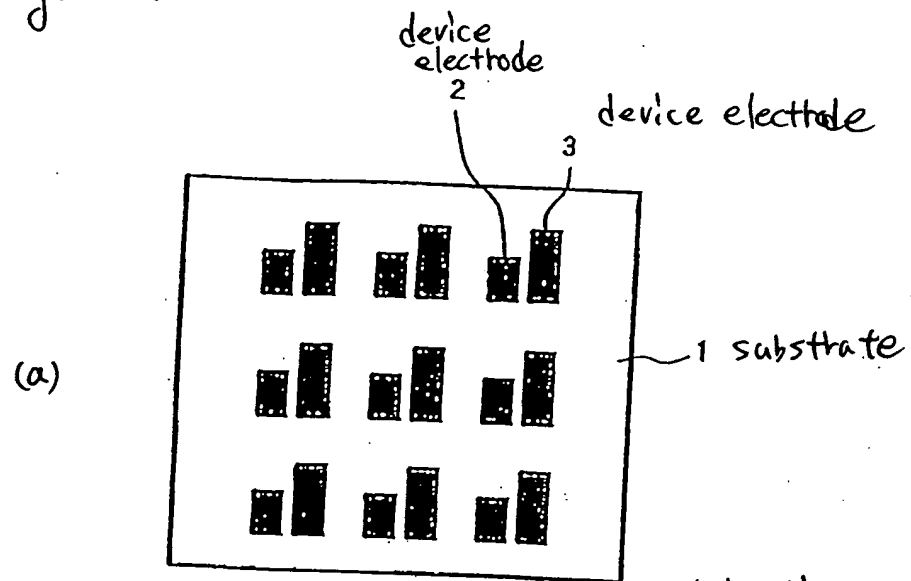
【Fig. 2】



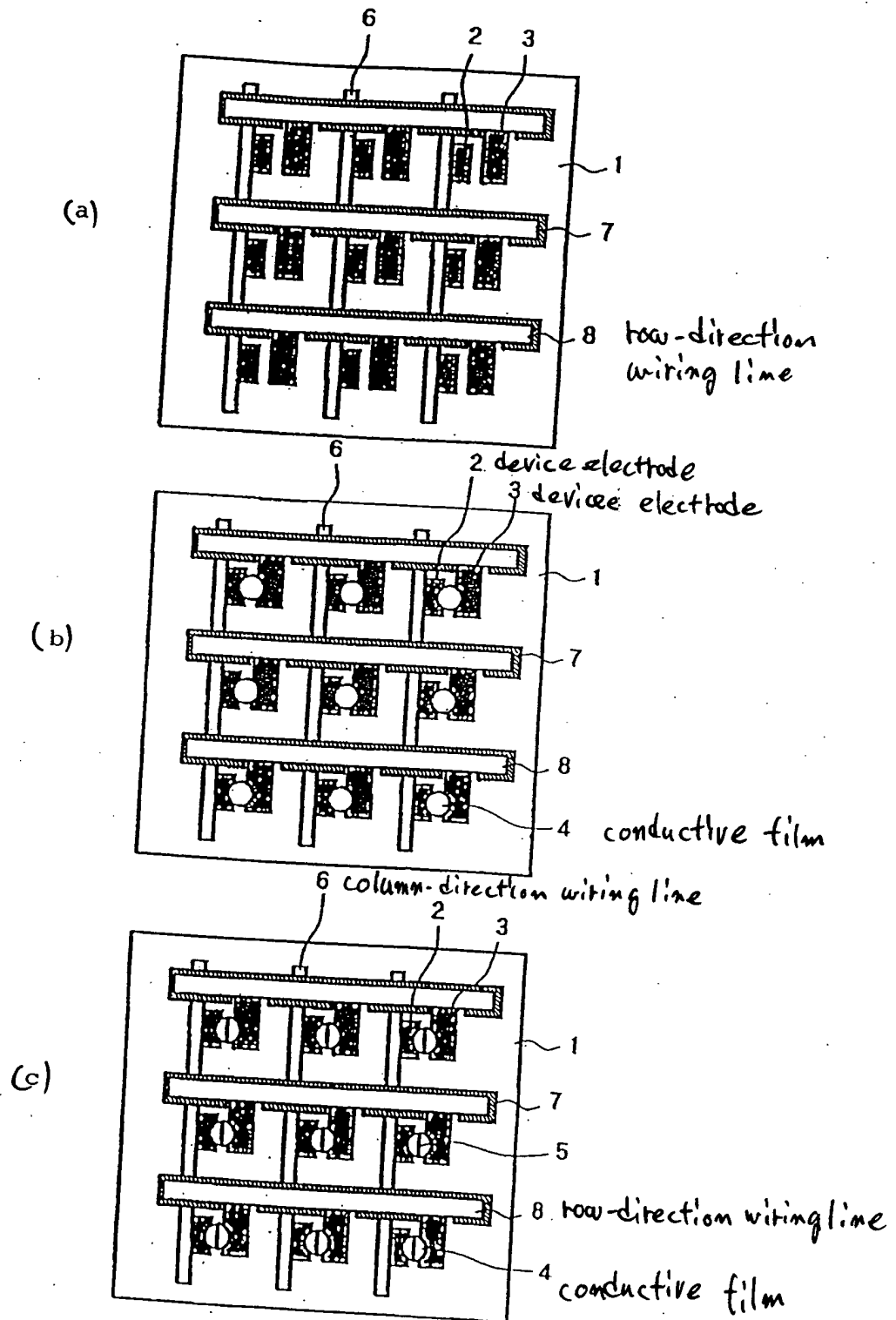
【 Fig. 3】



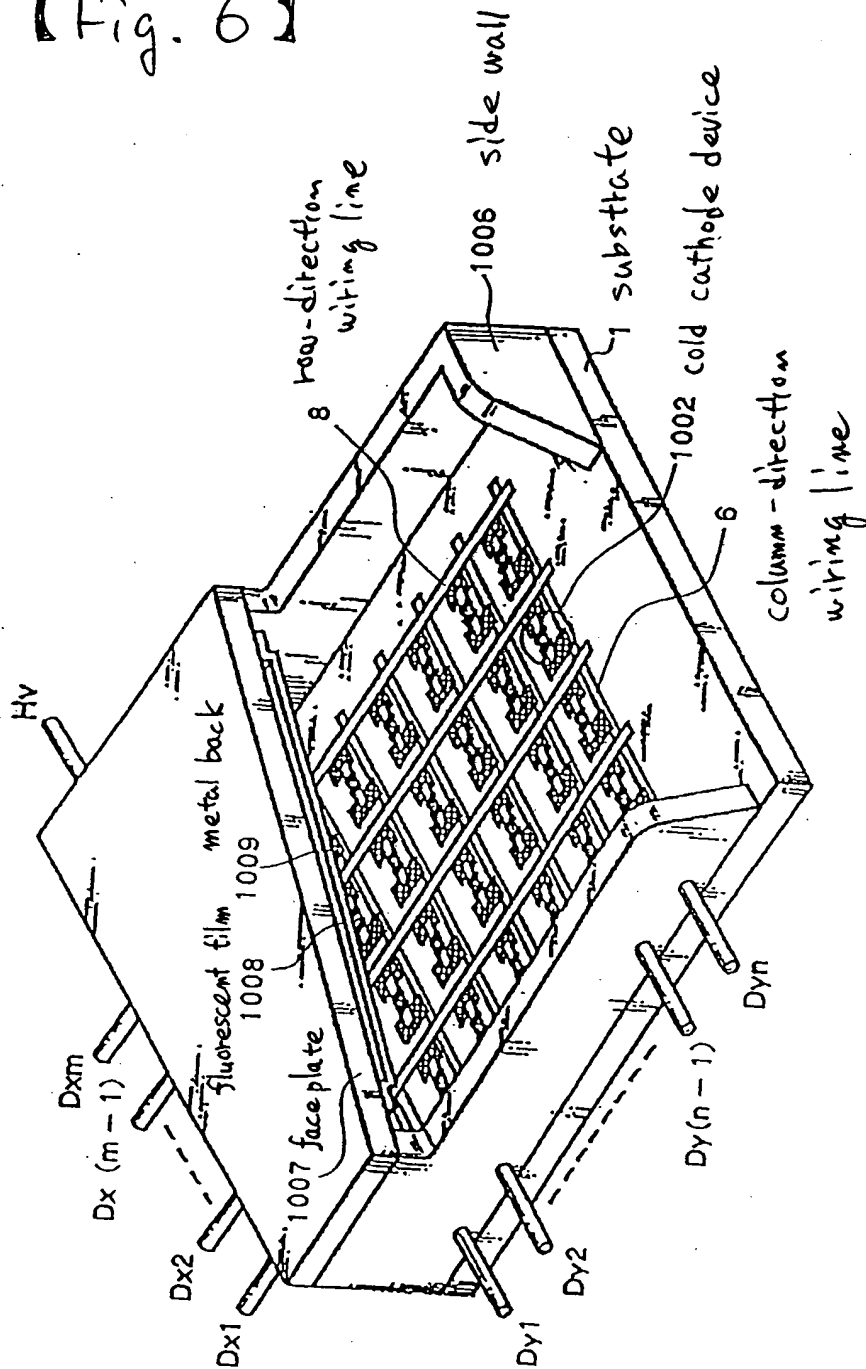
【Fig. 4】



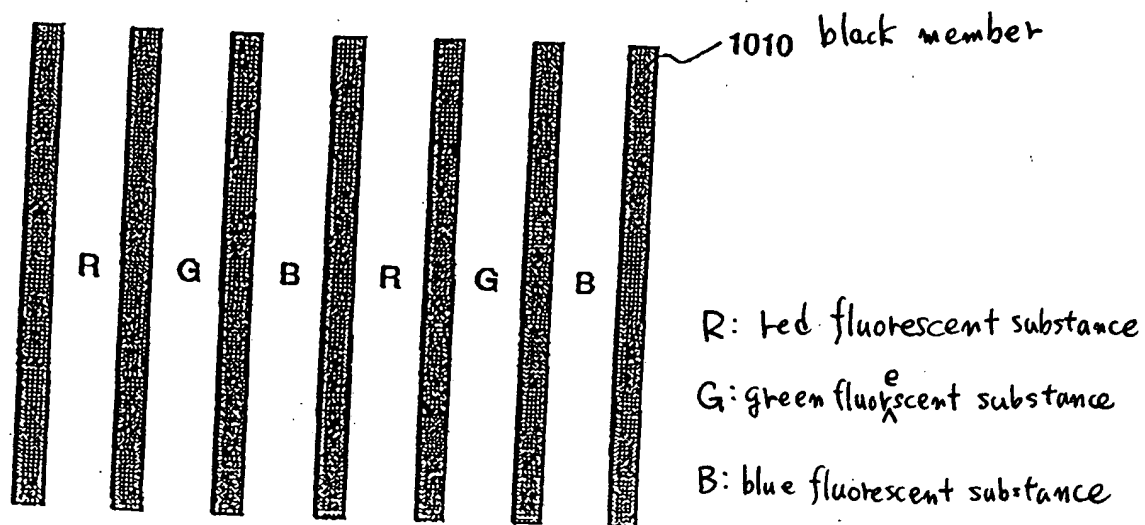
【Fig. 5】



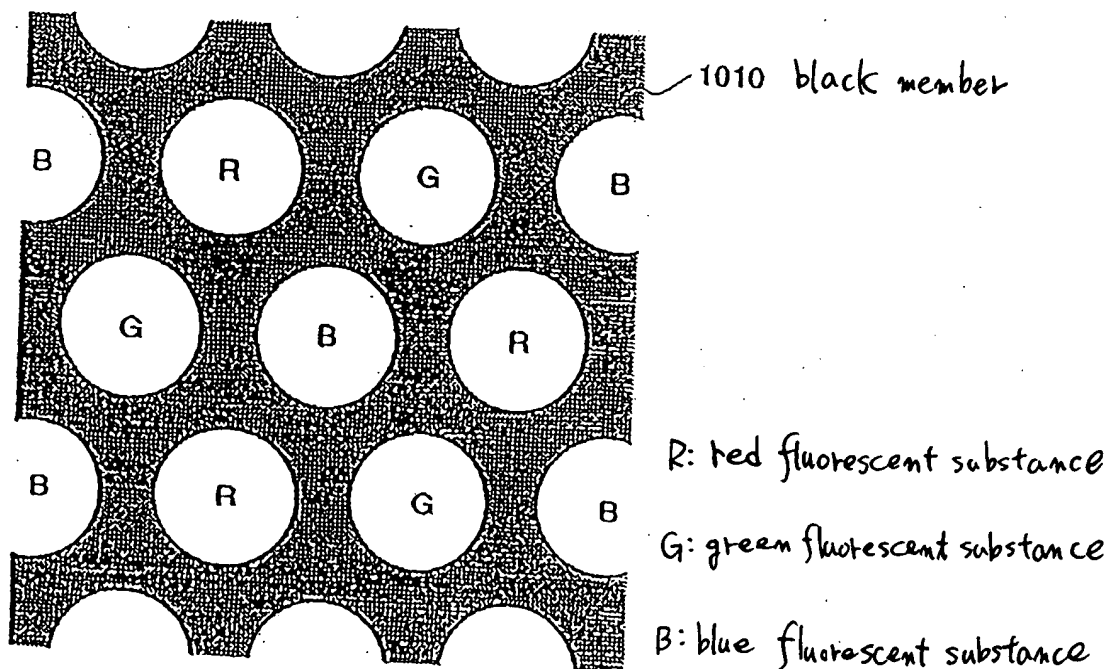
【Fig. 6】



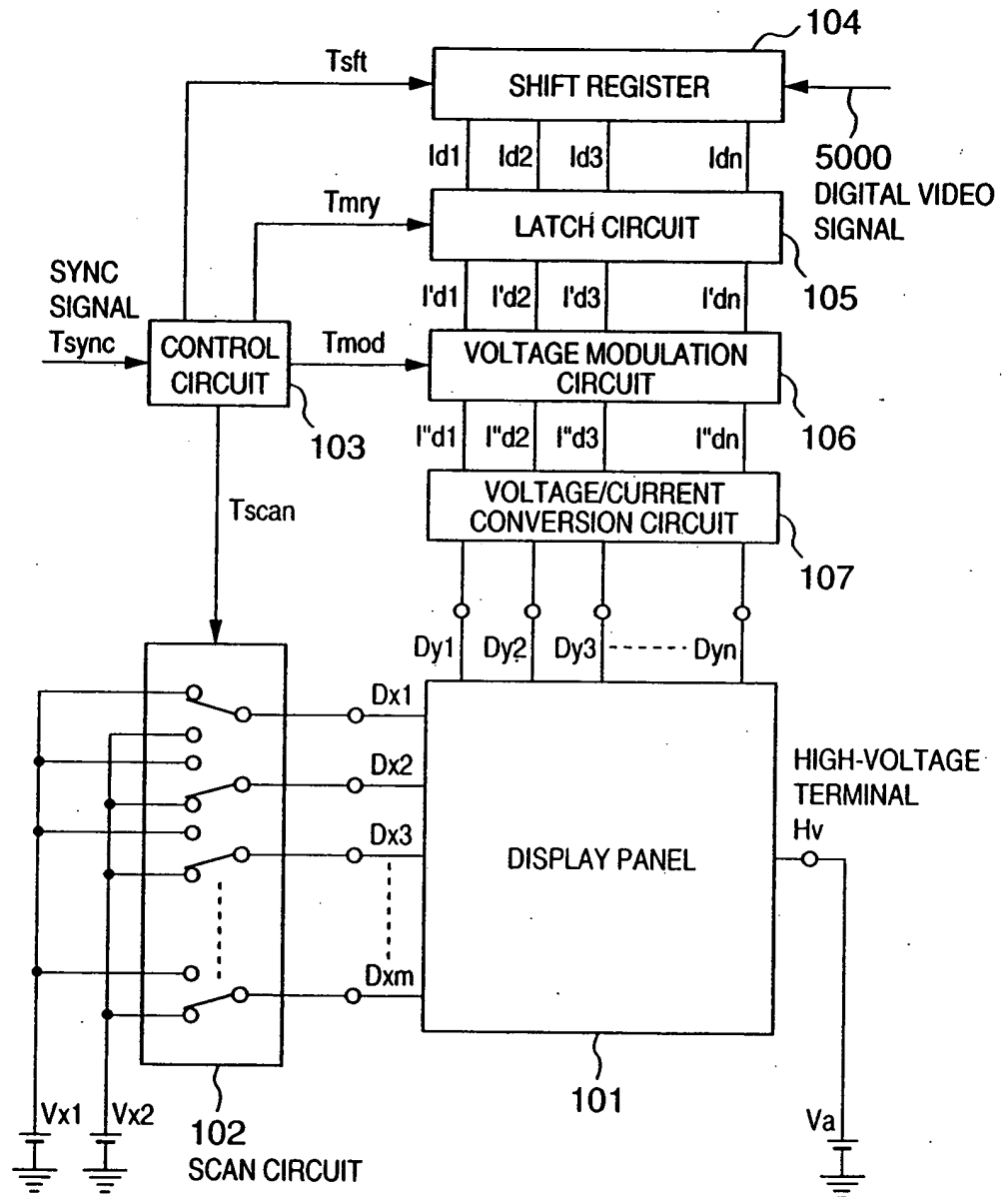
【Fig. 7】



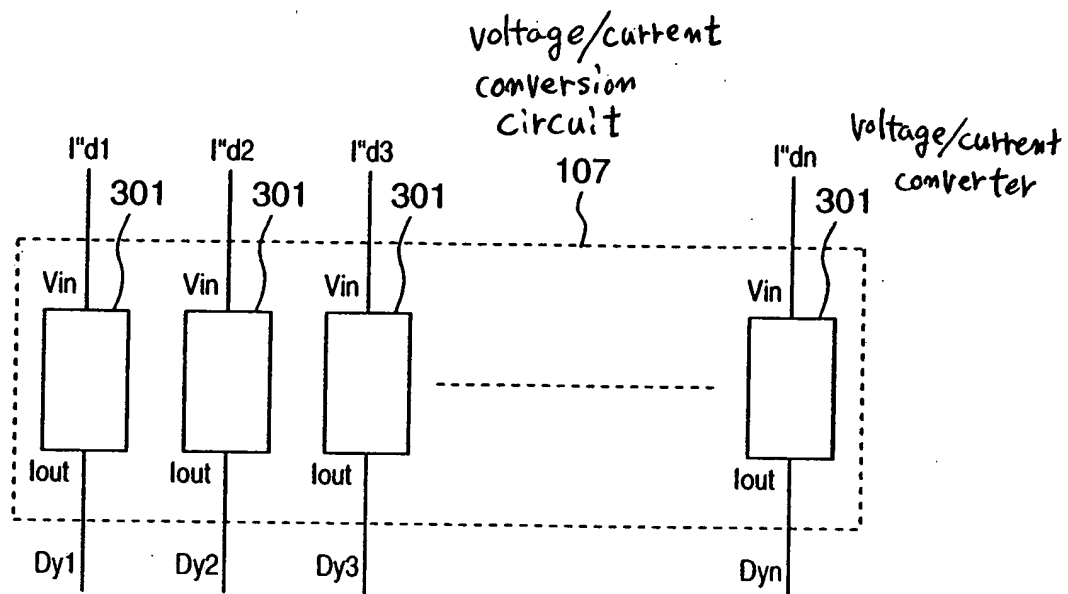
【Fig. 8】



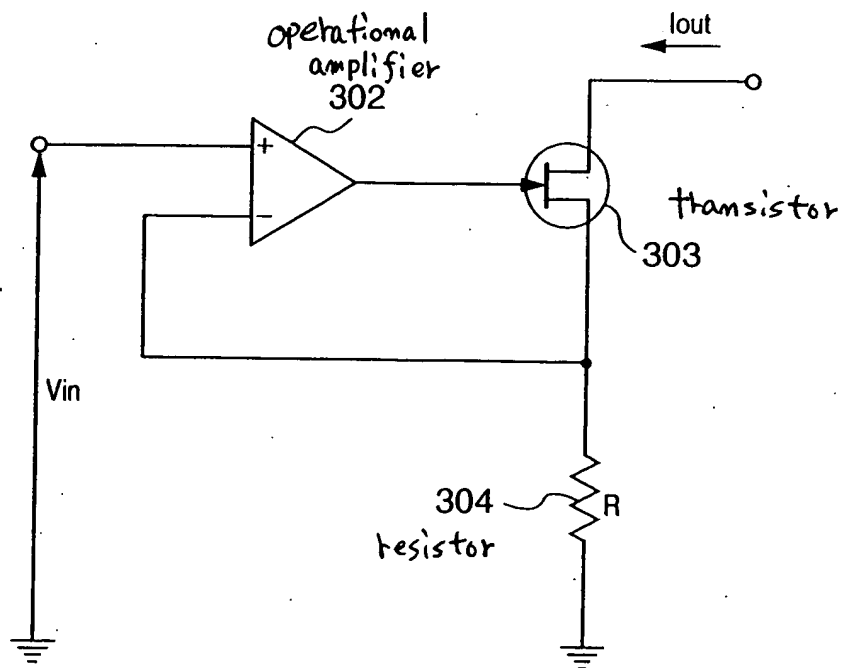
【Fig. 9】



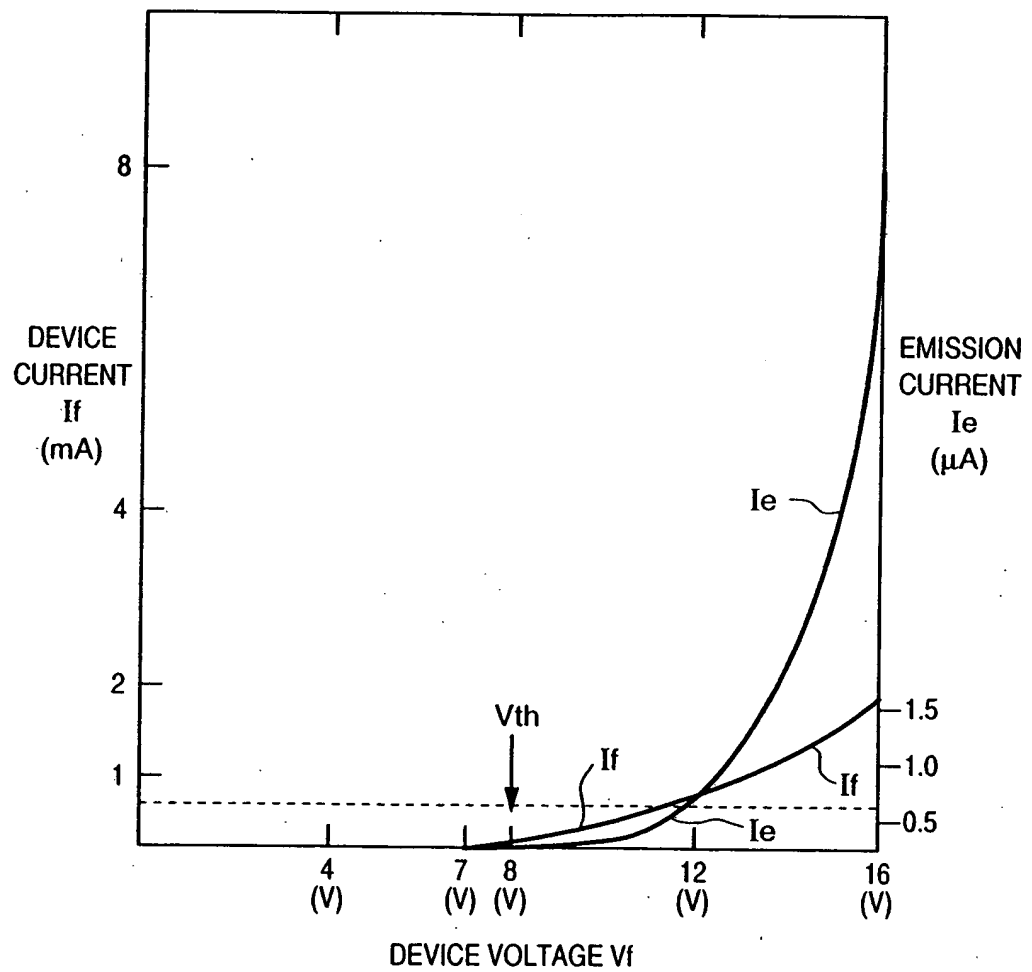
【Fig. 10】



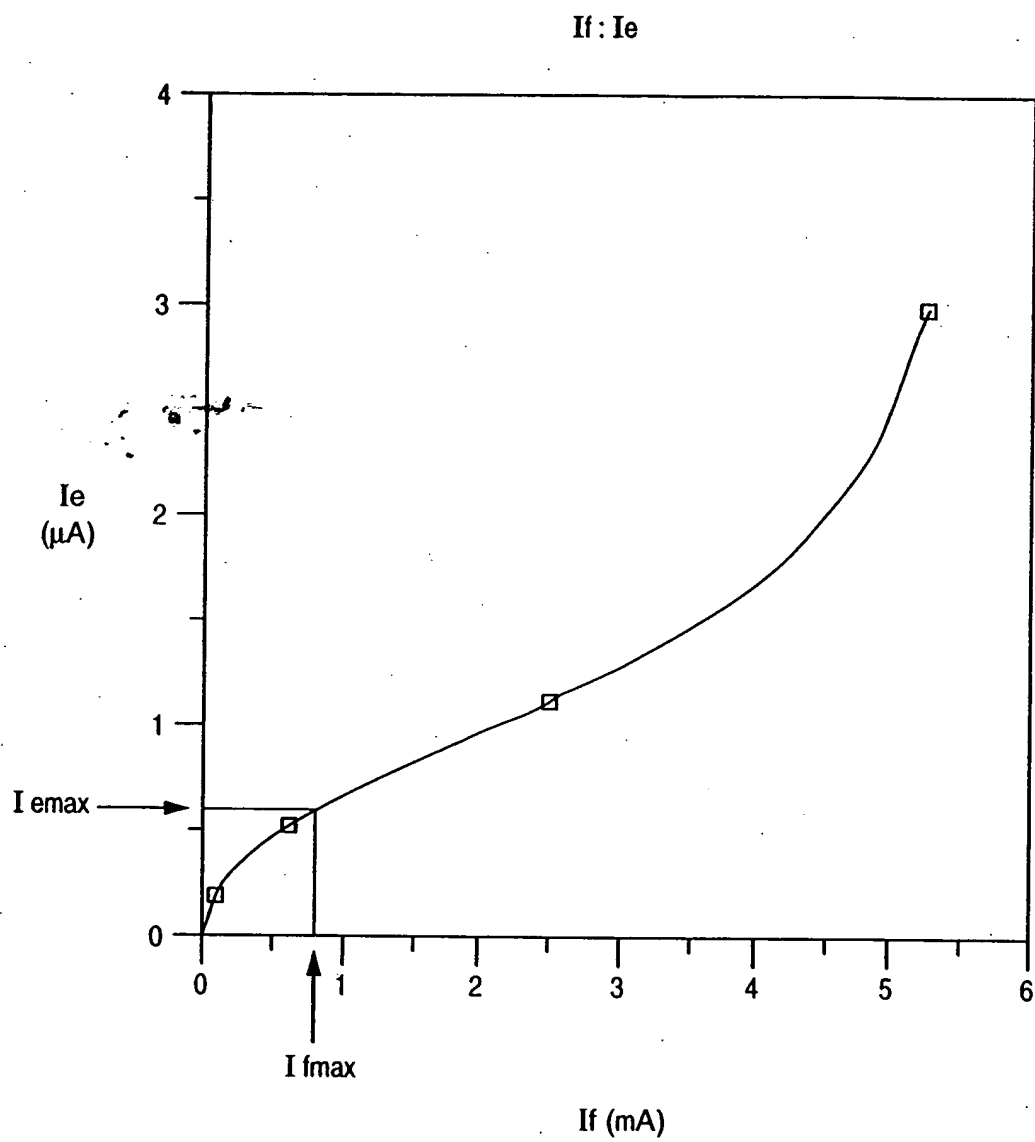
【Fig. 11】



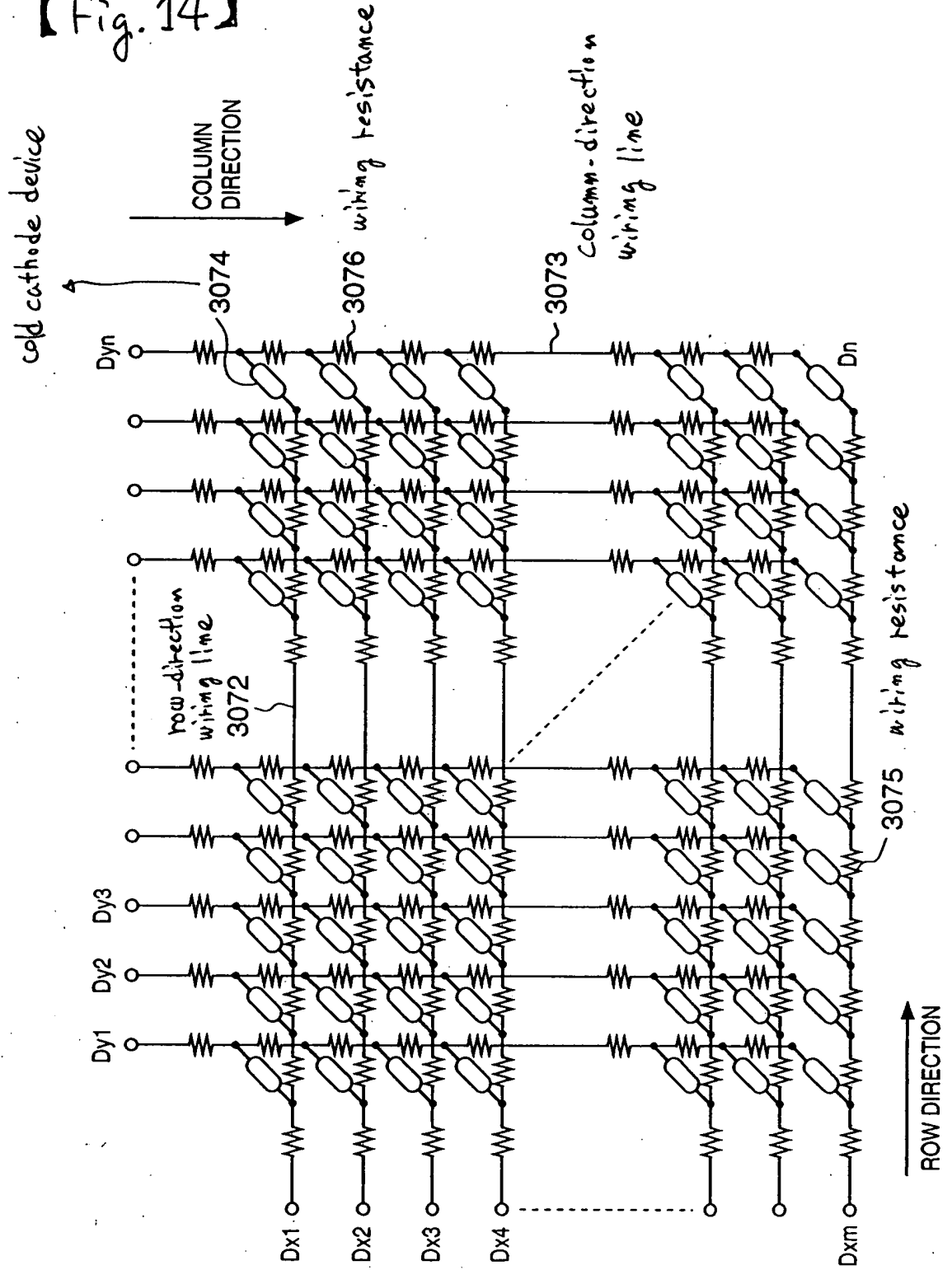
【 Fig. 12 】



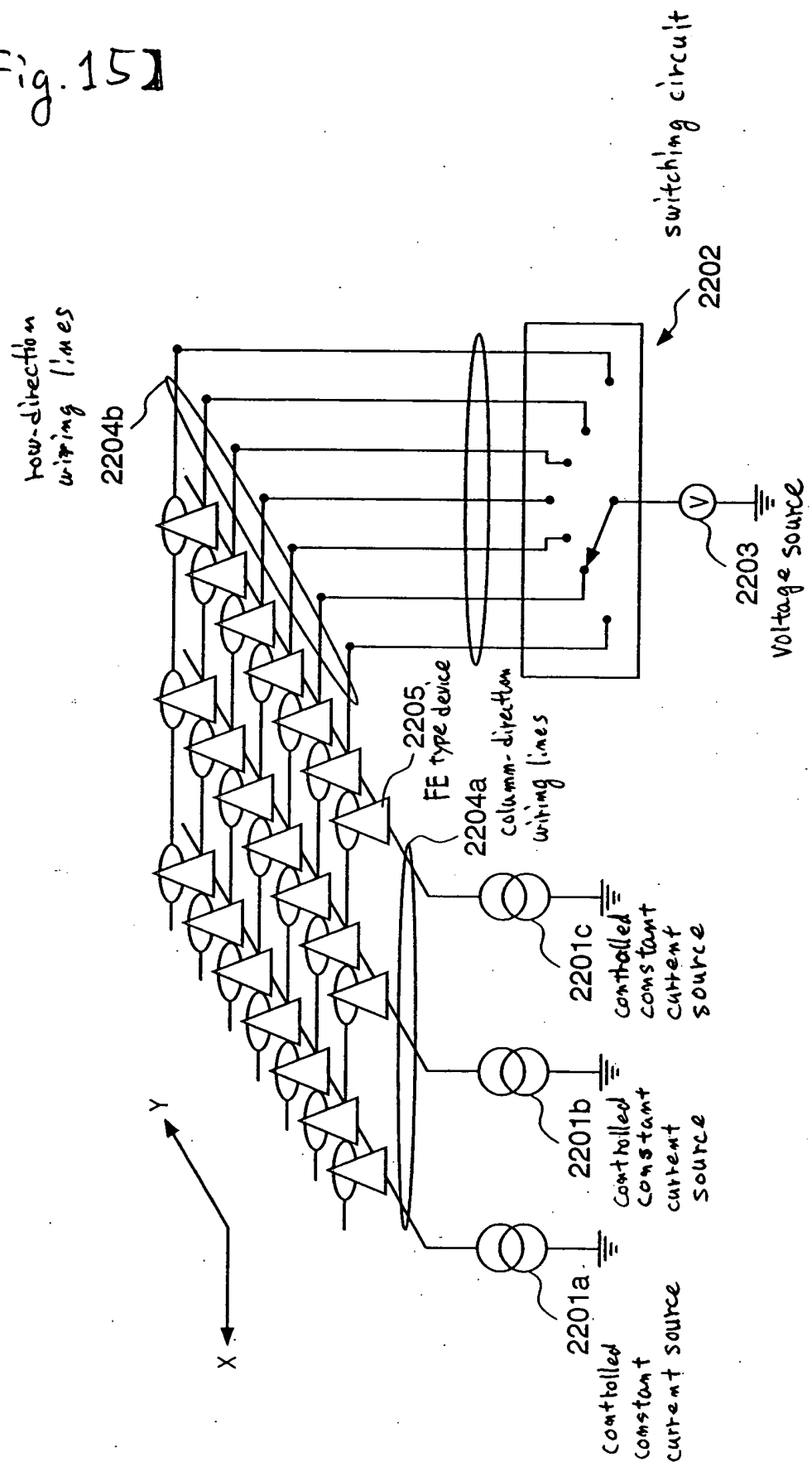
【Fig. 13】



【Fig. 14】



【 Fig. 15 】



[Type of the Document] Abstract

[Abstract]

 This invention is capable of suppressing variations
in electron emission state from electron-emitting devices
5 even with an arrangement using spacers.

[Means of Solving the Problems]

 A plurality of row-direction wiring lines 8 and a
plurality of column-direction wiring lines 6 are formed on
a substrate 1 so as to cross each other. An
10 electron-emitting device made up of device electrodes 2,
3, a conductive film 4, and an electron-emitting portion
5 is formed at each intersection between the row-direction
wiring line 8 and the column-direction wiring line 6. The
spacers 9 are arranged on some of the row-direction wiring
15 lines 8. The column-direction wiring lines 6 are
respectively connected to controlled constant current
sources 221a, 221b, 221c serving as current sources capable
of outputting desired current values. The respective
row-direction wiring lines 8 are connected to a voltage
20 application means constituted by a voltage source 223 and
a switching circuit 222 for selecting the row-direction
wiring lines 8 while sequentially scanning them.

[Selected Drawing] Fig. 1